Modeling Facial Signs of Appraisal During Interaction; Impact on Users' Perception and Behavior

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ABSTRACT

Interactive virtual characters are expected to lead to an intuitive interaction via multiple communicative modalities such as the expression of emotions. Generating facial expressions that are consistent with the interaction context is a challenge. This paper presents our interactive facial animation system based on the Component Process Model, generating facial signs of appraisal during a real-time interactive game. We describe a study comparing our model to the categorical approach of facial animation of emotion. Participants interacted with a virtual character in three conditions: no expression of emotion, an expression of a categorical emotion, and expressions of sequential signs of appraisal. The character in the appraisal condition was reported as being more expressive than in the other two conditions and was reported as experiencing more mental states. In addition, using appraisal signs modified the way participants interacted with the character (participants played slower after some emotions were expressed by the agent, i.e. pride and sadness).

Categories and Subject Descriptors

[I.3.7] Animation, [H.5.2] Evaluation/methodology, GUI

Keywords

virtual characters; facial animation; model; affective computing

1. INTRODUCTION

Given the important role of emotion signaling in social relationships, humans must be able to accurately encode and decode emotional states that change extremely rapidly [1]. Similarly to humans, virtual characters (hereafter VC) often express emotions using facial expressions. VCs are commonly used in interactive applications such as games or e-learning environments. Several studies have revealed the importance of VC having a proper emotion model, dynamics and facial expressions to be well perceived and accepted by the participants [2]. The underlying models of emotion constitute a challenge in affective computing research [3] and endowing VC with subtle expressivity requires theoretical and empirical studies [4].

VC are used as tools for conducting experiments on how humans perceive communicative signals [5,6,7,8]. Most of these systems rely on prototypical expressions of a small set of basic emotions, such as anger, sadness, joy, fear, surprise and disgust [9,10] although VC are however capable of expressing subtle differences in facial expressions [11].

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Despite the general acceptance of the notion that emotion is a dynamic process, few emotion theories specify mechanisms that allow analyzing or modeling dynamic changes over time.

Furthermore, basic emotion theories have the disadvantage that they describe only a few emotions in detail and provide little description on how to consider more complex emotion and blends of multiple emotions. Blends of several emotions are observed in natural settings [12,13] and have been modeled in some VC [14].

According to cognitive theories, emotions result from a process of evaluation (also called appraisal) of the situation and its relation to the individual experiencing the emotion [1]. Several appraisal models have been proposed in psychology [15] and computational models have thus been defined and implemented [16]. Yet, few appraisal-based systems are used for real-time interaction, and little is known about how such systems should impact real-time interactive facial animation. Canned animations based on appraisal modeling have been presented to subjects who had to rate them outside any interaction context [17]. Such perception tests limit the exploration of cognitive theories of emotions and the associated dynamic models of emotions because these theories strongly rely on the appraisal of the current context.

In this paper, we present an interactive system inspired from the CPM model for the animation of a VC's facial expressions during a competitive game. This system is evaluated using a user study assessing how a VC that sequentially displays facial signs of appraisal was perceived during a real-time interactive game. We compared appraisal based animation to a VC displaying only categorical emotions or no emotion at all. Our general hypothesis is that the condition impacts participants' perception of the expressivity of the VC and of its mental states. We also expect an impact on participants' behavior during the game since facial expressions can be a powerful means of conveying information related to the playing strategy of the character.

The remainder of the paper is organized as follows. Section 2 summarizes related work in psychology of emotions and in interactive VC research. Section 3 presents the MARC (Multimodal Affective Reactive Character) platform that we extended to enable the dynamical display of sequential signs of appraisal by our VC. This platform enables the generation of sequential displays of facial signs of appraisals during an interactive application. Section 4 presents our participant study and details our hypotheses. Section 5 and 6 present and discuss the results. Section 7 concludes and explains our future research directions.

2. RELATED WORK

2.1 Emotions and Theories

Theories of emotion assume the existence of several emotional components, for example, cognitive processes, peripheral physiological responses, motivational changes, motor expression, and subjective feeling. Psychological theories of emotion differ in their assumptions on how these emotion components are integrated and, in particular, how qualitatively different emotional states are to be differentiated with respect to their patterning [18]. Several approaches to emotions have been proposed, such as categorical [9], dimensional [19] and cognitive [20]. We consider hereafter two classes of theories that are relevant to our research: the categorical emotions theories and the cognitive theories of emotions. These two approaches are strongly related to the communicative function of emotions, and more specifically to the facial expressions of emotions.

Some authors have made a distinction between *emotional states* (e.g. joyful, being proud, etc.) and *other cognitive mental states that are not directly related to emotions* (e.g., knowing, thinking, pretending) [21]. Baron-Cohen has proposed a detailed list of 416 mental states including emotional states and non-emotional cognitive mental states. The MindReading database includes videos of acted facial expressions of these mental states [22].

2.1.1 Categorical approach to emotions
According to the categorical approach to emotion, there is a set of basic emotions, such as joy, surprise, fear, anger, sadness, and disgust [9]. According to Ekman, several characteristics distinguish these basic emotions from one another as well as from other affective phenomena [23]. These basic emotions are supposed to be triggered by specific conditions by response programs that might be universal. Each emotion is characterized by a specific circuit. A basic emotion is not seen as a single affective state, but rather as a family of related states. Different researchers [24,25,26,23] have considered different lists of fundamental emotions (for example, including interest and shame). This approach is highly centered on facial expressivity and proposes a list of "universal" expressions. It was extensively used in VC animation [2].

2.1.2 Appraisal theories of emotion
Appraisal theories are part of the cognitive approach to emotion. Emotions result from a process of evaluation of the situation and its relation to the individual [27,28,1,29]. Scherer has argued that emotions are generated through cycles of multi-level evaluations of events. Several different evaluations assess the significance and implications of a particular event for the survival or well-being of the organism. These evaluations are called appraisals. Scherer has proposed four main evaluation phases: 1) relevance, 2) implications, 3) coping potential, and 4) normal significance. Each phase is decomposed in several criteria, known as sequential evaluation checks (hereafter called checks). Scherer has defined several sets of checks but often focus on five to seven checks [30].

Checks may have multiple effects on the face, the body posture, the voice and the nervous system [31]. The timing and order of these checks are crucial to a proper implementation of a computational model. For instance, a study has observed that the unpleasantness check is evaluated prior to the goal hindrance check [32]. This study also provided muscles reaction delays for these checks (about 400ms for unpleasantness and 800ms for goal hindrance). Another study has suggested that the three first checks (expectedness, unpleasantness, and goal hindrance) occur in the brain within 250ms [33]. Higher level checks, such as coping potential and immorality, might induce longer delays, but little data is available in the literature about these delays.

2.2 Basic emotion vs. appraisal theories: what about facial expressions?
Basic emotion and the appraisal theories suggest different mechanisms underlying the generation of facial expressions. The basic emotion theory supposes the existence of a "prewritten program" for each discrete emotion. Tomkins suggested that the expressivity mechanism is a neuromotor program, predicting that following emotion elicitation, the prototypical pattern will be produced [24]. Instead, the component process model based on appraisal theories considers that an emotion is an emergent process during which several elements of the expression appear and combine in time. These two different mechanisms result in very different facial expressive patterns. In the categorical approach, a prototypical facial expression pattern is then selected among a family of expressions and displayed. According to the component process model, the eliciting event is sequentially appraised according to a series of sequential evaluation checks, each producing a facial action. These facial actions combine in a dynamic fashion, producing a large variety of different patterns. According to [34] each of these individual components contributing to a facial expression is inherently meaningful.

Basic emotion and appraisal theories differ according to the number and the prototypically of the facial expressions. A study compared categorical and appraisal-related facial expressivity [35]. Twelve actors were asked to perform scenarios covering 14 emotions. No complete prototypical pattern was observed for basic emotions, contrary to the predictions that one would expect based on the categorical approach. Even the occurrence of partial patterns was relatively rare (1/3 of the portrayals). These observations can be interpreted as evidence against a strong affect program mechanism. Expression patterns show much more variability than one would expect on the basis of discrete emotion theory [1].

2.3 Emotional Intelligence and the attribution of mental states to others
In order to understand how users perceive VC expressing emotions, we need to consider two important notions: *emotional competence* and *emotional intelligence*.

Emotional competence [36] requires 1) to express appropriate emotions, which require adequate appraisals of internal goals states, coping potential, and the probable consequences of events, and 2) to differentiate emotions and to understand emotion blends, which implies a correct estimation of coping potential and accurate assessments of social expectations, norms, and moral standards.

Emotional intelligence is defined as "the ability to recognize and regulate emotions in ourselves and in others" [37] . This capacity spans from basic cognitive processes to more complex combinations of cognition and emotion processes: 1) perceive, evaluate and express emotions (one's own and others' emotions), 2) use emotion during information processing, 3) differentiate and label different emotions, and understand emotion blends, and 4) organize one's own emotion for supporting social goals. Emotional intelligence would thus enable individuals to engage in interactions while controlling their own emotions and those of other individuals. Several questionnaires have been proposed to measure the specific skills of emotional intelligence [38].

2.4 Virtual Facial expressions of emotions

Since the early 1970s, research in computer graphics has attempted to simulate the human face which is perceived as a powerful communication tool for human-computer interaction. Facial expression of emotion in virtual characters mostly focused on displaying basic emotions [39]. Some systems feature the ability to blend several emotions on the whole face or using spatial facial region decomposition. Some systems also use dimensional models of emotions [40] or sequenced expression models [41].

A sequential facial animation system using Scherer's descriptions of facial signs of appraisals has also been implemented by [17]. The system displays temporary expressions of appraisals checks but was not interactive and did not provide animation context. A study [42] addressed dynamic issues comparing two modes (sequential vs. additive AU) to animate facial signs of appraisals. Subjects were asked which emotion they recognize in each of the canned animation. The additive mode showed recognition rates above the chance level, whereas the sequential mode gave recognition rates marginally above chance level.

3. REALTIME SIGNS OF APPRAISAL

3.1 The game application

Two-player turn-based games such as chess are relevant for affective computing research [43]. We selected and implemented a game called Reversi (Figure 1). This competitive game is played by two players on an 8x8 grid board. This game is easy enough to learn, features a small set of possible events and hence sounds appropriate for conducting experimental studies about appraisals.

Figure 1. Participants played Reversi against a VC. A touch screen was used to interact with the Reversi board.

3.2 MARC

MARC is a framework composed of several models and tools for designing interactive expressive characters [44].

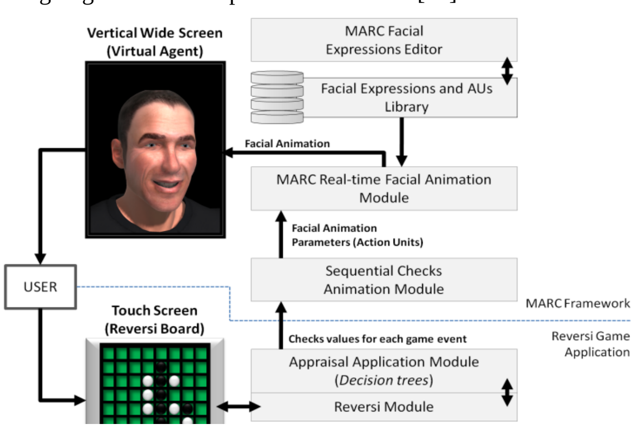


Figure 2. The MARC Framework adapted to Reversi.

In order to investigate appraisal theories during interaction, we extended MARC with two modules (Figure 2): 1) the "Appraisal Application Module", which appraises the events that occur during the game, and 2) the "Sequential Checks Animation Module", which generates corresponding facial animation parameters.

3.3 The appraisal application module

This experimental setting is relevant for our research by enabling us to focus on a restricted set of emotional situations with different appraisal profiles. Three actions trigger emotional events in the system: 1) the participant plays, 2) the VC plays, and 3) the game is over. We adapted a subpart of the component process model [31] that is relevant to these three emotional events. Our system thus deals with seven appraisal checks: expectedness, unpleasantness, goal hindrance, external causation, coping potential, immorality, and self-consistency. We chose these seven checks because they are relevant for the Reversi game. Moreover, several emotions have already been described according to those checks in psychological studies facilitating their implementation in a computational model [31]. The interaction contexts that we consider are the game event history and a short term anticipation of the participant's next two potential actions. Anticipating the game covers the appraisal checks of expectedness and coping potential: for example, the system expects that the participant will move one of his pieces towards a place where it will reverse some pieces belonging to the system. We did not enable our system to have a larger prediction about the game so as to give to the player a chance to win.

For each event, the appraisal module uses a predefined decision tree to compute a value for each of the seven checks. To design these trees, we predefined groups of check values that match several situations that might occur.

3.4 The animation module

The animation module generates temporary facial expressions of checks and creates the resulting dynamic sequence of facial expressions. Temporary facial expressions of check were specified using FACS descriptions of appraisal effects [31].

Figure 3. Frames of the VC's expressions: control condition, categorical condition (sadness), appraisal condition (sequence leading to sadness with the following values of appraisal checks: unexpected, unpleasant, high goal hindrance, no coping potential).

At the end of the sequential check animation, the animation module displays the final emotional state resulting from the appraisal sequence. We selected the following set of emotions: joy, fear, anger, sadness and pride. This set was selected because the literature has provided descriptions for their potential appraisal profile and the values of the checks [31], and these emotions are often observed during a game.

The final facial expression for joy, fear, anger and sadness were defined using Ekman's description [9]. The design of this final facial expression of pride was inspired by the MindReading database [22]: we selected the features of the facial expressions, (e.g. brows movements) appearing in at least half of the six videos illustrating pride.

Figure 3 (bottom line) provides an illustration of such a sequence of facial expressions of appraisals.

3.5 Prior perceptual validation of the facial animations of appraisal

Before proceeding to the actual experiment about the perception of facial expressions during the game interaction, we validated the perception of individual sequences of expressions of appraisals.

In a previous study, we observed that the facial expressions of basic emotions (including joy, fear, anger, and sadness that we used in this study) displayed by our VC were recognized by participants above the chance level [45].

Sequences of facial expressions of appraisals were validated as follow. Animations were designed according to suggestions from the literature [31]. Nine sequences of facial expressions that were possibly used during the Reversi game were tested. In total, 109 individuals participated in this study. There were 23 males and 86 females. The average age was 20.82 years. Each participant saw one animation. Each animation was seen and rated by an average of 12 participants. Participants had to fill the Geneva Appraisal Questionnaire, which aims at studying the relations between emotions and appraisal checks [31]. We adapted this questionnaire to our setup (e.g., participants had to rate the emotions expressed by our VC instead of self-reporting their own emotions). We observed that the appraisal and categorical profile of the nine animations were recognized by participants above the chance level.

4. Study

We conducted a study to evaluate the impact of the facial expressions of the VC on participants' perception during a Reversi game. We compared 3 expressive conditions (Figure 3):

1) A neutral condition, i.e., the VC did not display any facial expression of emotion; participants in this group will be referred to as the "control group"
2) A categorical condition, i.e., the VC displayed an animation based on interpolation of prototypical facial expressions of categorical emotions;
3) An appraisal condition, i.e., the VC sequentially displayed facial expressions of appraisal checks reflecting an underlying sequential appraisal of the current situation.

In the appraisal condition, the values of the checks External Causation, Immorality and Self consistency were not expressed using individual facial expressions. They were used instead in the final computation of the resulting emotion expressed at the end of the sequence. Animations in the categorical condition and the appraisal condition had the same duration.

4.1 Hypotheses

Regarding the question of how the condition influenced participants' perception, we had the following hypotheses in mind:

H1: The perceived emotional expressiveness of the VC increases with the number of facial expressions used in the condition

The VC displays expressions of emotion in the appraisal group and in the categorical groups. We expect that participants playing in these two conditions will report perceiving expressions of emotions.

H1A: Participants perceive less emotion in the VC's expressions in the control group than in the categorical and appraisal groups.

<u>Perception of expressions of emotion</u>:
control group **<** (categorical group **=** appraisal group)

We expect that participants will also perceive the difference of dynamics between the animations used in the three groups.

H1B: Participants perceive a higher dynamics of emotional expression when the number of facial expressions is higher.

<u>Perception of the dynamics of emotional expression</u>:
control group **<** categorical group **<** appraisal group

H2: Participants' attribution of emotional states and other cognitive mental states to the VC depends on the condition

Because the VC displayed expressions of emotion in the appraisal group and in the categorical group, we expect that participants in these two groups will attribute internal emotional states to the VC.

H2A: Participants attribute less emotional states to the VC in the control group than in the categorical and appraisal groups.

<u>Attribution of internal emotional states</u>:
control group < (categorical group = appraisal group)

The appraisal condition features expressions of cognitive evaluations of the situation. Thus, we expect that participants will also attribute more non-emotional cognitive mental states (e.g., thinking) to the VC than in other conditions.

H2B: Participants attribute more non-emotional cognitive mental states to the VC in the appraisal groups than in the control group and categorical group.

<u>Attribution of non-emotional cognitive mental states</u>:
(control group = categorical condition) < appraisal condition

H3: Participants win more often and spend more time to play when the number of facial expressions is higher

We expect participants to win more often in the appraisal and categorical groups than in the control group because they can rely on more feedback to understand and predict the behavior of the VC.

H3A: Participants win more often when the number of facial expressions is higher.

<u>Participant wins</u>:
appraisal condition > categorical condition > control group

Finally, we expect participants to spend more time to prepare and make their moves in the appraisal condition than in the categorical condition because they will have to interpret a higher number and variety of facial expressions.

H3B: Participants spend more time to play when the number of facial expressions is higher.

<u>Game duration</u>:
appraisal group > categorical group > control group

4.2 Method

4.2.1 Design and participants

The experiment used a between-participants design with the independent factor "expressive condition" as a single factor (control, categorical and appraisal).

Sixty participants took part in the study, all French native speakers. There were 17 females and 43 males. The average age was 26 years (SD 8.39). Participants had either a high school degree or a university degree. Participants were distributed randomly in three groups of twenty participants each.

4.2.2 Procedure

Participants were informed that they would play Reversi against a VC. They were left alone with the computer in a quiet room. The participants were video recorded to collect additional information about the interaction.

Participants played first. The board game was darkened when the participant made a move so as to direct participants' attention to the VC's facial expressions rather than the board at these emotionally relevant moments. The VC expressed the emotion resulting from the evaluation of the participant's move according to the condition. Then the VC played, and its face expressed the emotion reflecting the evaluation of the new situation. The board game was displayed again so that the participant could play the next move.

4.3 Measures

4.3.1 Subjective measures

The questionnaire comprised two parts. Part I aims at analyzing participants' perception of the facial expressions displayed by the VC. Part II aims at studying the internal emotional states and non-emotional cognitive mental states that participants attributed to the VC. In each of these two parts, a list of claims was proposed. For each of these claims, participants had to report their level of agreement according to a 5-point Likert scale. The claims were inspired by questionnaires measuring emotional intelligence [38].

The reliability of our questionnaire was checked using Cronbach's alpha. We computed Cronbach's alpha (CA) for the dimensions related to the perception of facial expression, the attribution of emotional states and the attribution of non-emotional cognitive mental states. The values were quite satisfactory according to the APA recommendations (between 0.70 and 0.94).

Part I: *Participants' perception of the facial expressions displayed by the VC*
The goal of this first section is to test our first hypothesis (H1)

Perception of emotional expressions. 5 items (CA: 0.85);
*Perception of an absence of emotional exp*ressions 5 items (CA: 0.94);
Perception of emotional dynamics. 4 items (CA: 0.75);

Part II: *Attribution of emotional states and non-emotional cognitive mental states by participants to the VC*

The second part of the questionnaire concern the attribution of internal mental states by participants to the VC. It refers to our second hypothesis (H2): the attribution of emotional states and other cognitive mental states to the VC depends on the condition. This part of the questionnaire contains two sections:

Attribution of emotional states. 7 items (CA: 0.79);
Attribution of non-emotional states. 7 items (CA: 0.70);

4.3.2 Performance measures

Objective measures were also used to test the third hypothesis (H3). The outcome of each game session was collected as a binary variable (Win/Lost). We recorded the timestamps of all moves by the agent and participants. This record allowed us to compute the time participants took to prepare and make all their moves.

5. Results

The results presented in this section are statistically significant ($p<0.05$). Results are explicitly referred as a "trend" if p is between 0.05 and 0.1. Collected data for subjective (user point of view) measures were analyzed using the t-test.

We applied the Kolmogorov-Smirnov test to show that the following variables succeed to satisfy normality assumptions: perception of emotional expressions (K-S d=,13955, p<,20), perception of an absence of emotional expression (K-S d=,10497, p> .20), perception of emotional dynamics of expressions (K-S d=,10783, p> .20), attribution of emotional states (K-S d=,08757, p> .20), and attribution of non-emotional cognitive mental states (K-S d=,12263, p> .20).

We performed an ANOVA with expressive conditions as an inter-subject factor. Fisher's LSD was used for post-hoc pair-wise comparisons. All the analyses were performed with Statistica 9.

5.1 Subjective measures

H1: The perceived emotional expressiveness of the VC increases with the number of facial expressions used in the condition.

H1A*: Participants perceive less emotion in the VC's expressions in the control group than in the categorical and appraisal groups.*
The reported perception of emotional expressions was higher in the appraisal group than in the control group ($t(15) = -3.93$; $p < 0.001$).

Participants in the appraisal condition also considered MARC to have expressed more emotions that the participants in the categorical group ($t(18)=-2.05$; $p<0.05$).

Participants in the categorical condition perceived more emotional expressions than participants in the control group ($t(13) = -2.12$; $p < 0.05$). The agent in the control group was rated as globally less expressive than the agent in the categorical group ($t(13) = -3.88$; $p < 0.002$).

These results confirm our hypothesis H1A and moreover distinguish the appraisal group from the categorical group. The agent in the appraisal group was perceived as expressing more emotions that the agent in the categorical and control groups (Figure 4).

H1B*: Participants perceive a higher dynamics of emotional expression when the number of facial expressions is higher.*
The perception of emotional dynamics was higher in the appraisal group than in the control group ($t(15) = -2.06$; $p < 0.05$).

Yet, the control group and the categorical group were equivalent in terms of perception of expression dynamics ($t(13) = -0.83$; $p <$ 0.42 NS).

Finally, the comparison between the categorical group and the appraisal group revealed only a trend effect for the perception of dynamics of emotional expression ($t(18)=-1.87$; $p<0.08$). Figure 4 illustrates these results.

These results partly confirm our hypothesis H1B.

To summarize, we observed the following relations that partly confirm our hypothesis H1:

<u>Perception of expression of emotions:</u>
control group < categorical group < appraisal group

<u>Perception of the dynamics of emotional expression:</u>
(control group = categorical group) < appraisal group

H2: Participants' attribution of emotional states and other cognitive mental states to the VC depends on the condition.

***H2A**: Participants attribute less emotional states to the VC in the control group than in the categorical and appraisal groups*
Participants attributed a higher number of emotional states to MARC in the categorical and appraisal groups than participants in the control group ($t(13) = -2.40$; $p < 0.03$; $t(15) = -4.06$; $p < 0.001$) (see Figure 4)

Furthermore, we did not observe any significant differences between the categorical and appraisal groups in terms of attribution of internal emotional states. Participants in these conditions assigned the same number of emotional states to MARC.

These results validate our hypothesis H2A. Subjects attributed a higher number of emotional states when the agent expressed emotions.

***H2B**: Participants attribute more non-emotional cognitive mental states to the VC in the appraisal group than in the control and categorical groups*
The attribution of non-emotional cognitive mental states is higher in the appraisal group than in the control group ($t(15) = -2.87$; $p < 0.01$) (see Figure 4). There is no difference in the attribution of non-emotional cognitive mental states between the control group and the categorical group.

Yet, participants in the categorical and appraisal groups assigned as many non-emotional cognitive mental states to MARC.

This result does not completely validate our hypothesis H2B. Participants did not judge the agent in the appraisal group as having more non-emotional cognitive mental states than the agent in the categorical group.

To summarize, we observed the following relations:

<u>Attribution of internal emotional states:</u>
control group < (categorical group = appraisal group)

<u>Attribution of non-emotional cognitive mental states:</u>
control group < appraisal group
control group = categorical group
categorical group = appraisal group

5.2 Objective measures

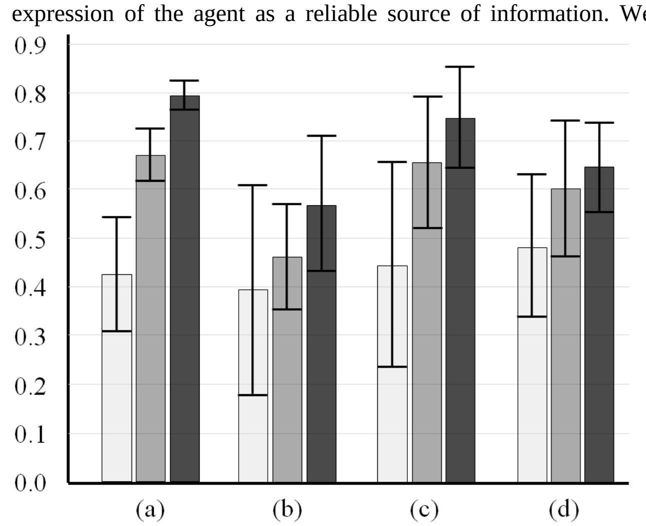
H3: Participants win more often and spend more time to play when the number of facial expressions is higher
The outcome of the game was analyzed with chi-square (χ^2) test. We observed that the outcome of the game depended on the group ($\chi^2(2) = 6.39$, $p < 0.04$).

We applied the Kolmogorov-Smirnov test to show that the following variable succeed to satisfy normality assumptions: total duration of the game (K-S d=0.15770, p<0.20).

Participants in the control group lost the game more often than participants in the categorical group and participants in the appraisal group. It seems that interacting with a VC that expressed emotions improved the performance of participants. Participants perceived these expressions of emotions and might rely on them to be more efficient.

The time that participants took to plan and make a move was analyzed by ANOVA using two variables: 1) the group and 2) the emotion expressed by the VC before each move. We also used Fisher's LSD for post-hoc pair-wise comparisons. Our results reveal that the total duration of a participant's actions did not depend on the condition ($F(2, 755) = 0.39$; $p = 0.68$ NS). The mean duration of a game was 9 minutes 50 seconds.

However, participants in the appraisal group only displayed some differences in the way they played depending on the emotion expressed by the agent. This result suggests that user uses the expression of the agent as a reliable source of information. We



(a) Reported perception of expressions of emotions of the virtual agent
(b) Reported perception of dynamics of emotional expressions
(c) Emotional states attributed by the participants to the virtual agent
(d) Non-emotional cognitive mental states attributed by the participants to the virtual agent

No-Emotion condition
Categorical condition
Appraisal condition

Note : All results were normalized by number of questionnaire items (0.0 to 1.0 range)

Figure 4. Summary of our experimental results

observed a trend effect depending on the agent's emotional expression before a participant's move ($F(2, 317) = 2.41$; $p = 0.09$). Participants played slower after that the agent expressed sadness than when the VC remained neutral following the previous move by the participant. A significant result was also observed for the emotion expressed by the VC following its own move ($F(2, 317) = 2.9265$; $p = 0.05$). Participants played slower when the character expressed pride than when it expressed joy.

These results partly confirm our hypothesis H3. Players were more efficient and won more often when they were playing against an expressive VC and even more often when the agent displayed sequential signs of appraisal. Besides, we observed that the emotion expressed by the character had some impact on participants' moves in the appraisal condition.

6. CONCLUSION

This paper presented a study exploring how participants perceive facial expressions of appraisal and emotion displayed by a VC during an interactive game. Our experimental results suggest some benefits of displaying dynamical emotional expressions inspired by appraisal theories of emotion. When the VC displays sequential facial expressions of evaluation checks, participants attributed more non-emotional cognitive mental states than in the control group. This result is in line with [34], who argued that the facial expression of each check have a particular emotional meaning. Our study suggests that these expressions of checks convey meaning regarding the agent evaluation process. The facial expression of a check might express both a cognitive and an emotional component. Thus, displaying facial signs of appraisal is likely to increase the perception that participants have of the cognitive capacities of the VC. Furthermore, no difference was observed between the categorical and the control groups in terms of reported non-emotional cognitive mental states. None of them featured the display of the cognitive evaluation of the situation.

However, we did not observe any difference between the categorical and the appraisal groups in terms of attributed non emotional cognitive mental states. An explanation might be found in the [46] who observed that static pictures of facial expressions of basic emotions allow human subjects to infer both emotion categories and the corresponding evaluation checks. Cognitive state might have been inferred in the categorical condition.

The expression of emotion by the VC had an impact on participants' behavior during the game. Participants relied on the emotions expressed by the agent to guide their actions and thinking. Subjects facing a VC expressing emotions used these emotions in a way that influenced their playing strategy. As a result, they won more often when the agent expressed emotion.

We also observed that participants in the appraisal group clearly took these subtle clues into account in their strategy, and that it did influence their behavior. We observed differences in the time that participants took to prepare the next move depending on the appraisals sequence displayed previously by the VC. Participants took more time to prepare a move following an expression of pride by the VC. This effect was not observed in the categorical group.

Our results suggest a difference between the instantaneous unconscious perception of signs of appraisal by participants (which impacts the way they play in the appraisal group) and the post-hoc report of perceived non-emotional cognitive mental states (no difference between the categorical and the appraisal groups). This difference points to the well-known complexity of measuring the perception of emotions and its impact on users.

7. FUTURES DIRECTION

The present study can be extended in several directions. The appraisals dynamics was hard set in our animation engine. However, [31] suggests that the dynamics is driven by the appraisal process, and durations of facial expression vary. Our system could take these possible variations into account. Using more complex dynamics in facial feature animation could also be explored, both in categorical and appraisal condition. It might lead to more realistic expressivity and animations.

The interaction context of our game application was intentionally restricted to some events occurring during the game to better control our experiment. We only considered seven checks of the component process model. This study can be extended to include other checks and other events. Using a more complete interactive context such as [47] might lead to a set of more complex emotions and possibly more realistic behaviors displayed one or several VC. Similarly, modern componential theories conceptualize appraisal as a recursive process; it is a constant effort for the individual to refine appraisal results and bring them into line with reality [36]. The result is a constant change of the qualitative nature and intensity of the resulting emotion. Implementing such a reappraisal process in our VC might also contribute to giving the perception of a more "emotionally intelligent" agent.

In the current setup, participants provided input only by indicating where to play using the touch-screen. Yet, dealing with participants' affective states in real-time is a key to create a real affective interaction loop and to enable a more sophisticated affective strategy in the VC.

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